



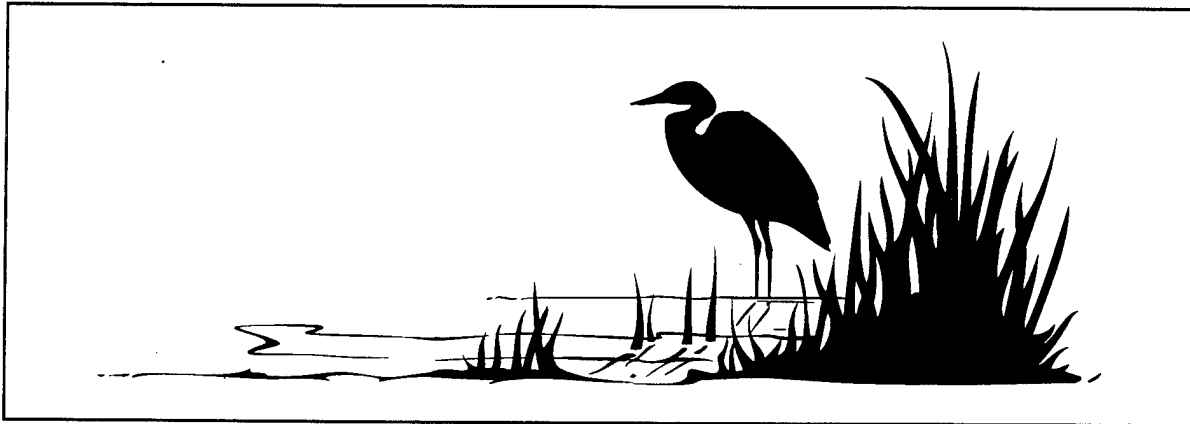
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A Literature Review of Actual and Potential Effects of Military Maneuvers on Avian Behavior, Reproduction, and Community Structure

by
Kevin J. Gutzwiller and Timothy J. Hayden



The Endangered Species Act, 1973 as amended, requires military installations to protect endangered birds and their habitats. Installations must fulfill their military training mission while limiting the associated impacts on birds. Currently, efforts to protect birds are hampered by a lack of knowledge about the actual and potential effects of military maneuvers.

This literature review examines reports of the effects of military activities on birds and the effects of certain maneuver-like recreational and natural-resource activities that produce disturbances similar to those induced by troop and mechanized movements.

Direct and indirect (habitat) effects are discussed, with emphasis on whether activities impacted avian behavior, reproduction, and community structure.

The quality of existing information is summarized in terms of its value for establishing causal relations. The types of information needed are identified so installations can meet their dual responsibilities of effectively training combat troops and protecting endangered birds.

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Foreword

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1 Introduction

Background

Numerous U.S. military installations are home to threatened and endangered birds. For example, black-capped vireos (*Vireo atricapillus*) and golden-cheeked warblers (*Dendroica chrysoparia*) occupy Fort Hood, Texas; Camp Pendleton, California, supports eight species that are Federally threatened or endangered, including the least tern (*Sterna antillarum*) and Bell's vireo (*Vireo bellii*); and Fort Benning, Georgia, is used by the endangered red-cockaded woodpecker (*Picoides borealis*) (Tennesen 1993). Of course, military installations were not established to preserve avian habitat; their purpose is to provide large areas for training combat troops and storing weapons. Today, base commanders are required by law (e.g., Endangered Species Act, 1973 as amended) to protect endangered birds and their habitats on Federal installations. At the same time, they must fulfill their military training mission. Only during the last 10 to 15 years have threatened and endangered birds received serious widespread consideration on military lands (Tennesen 1993). Currently, bases try to meet the difficult challenge of training soldiers effectively while limiting the associated impacts on birds (Diersing, Shaw, and Tazik 1992).

Efforts to protect birds are hampered by a lack of knowledge about the actual and potential effects of military maneuvers. Some work has been completed on the actual effects of military activities on birds, but the number of published peer-reviewed studies is limited, presumably because extensive scientific analysis of this issue is relatively recent. The results of ongoing research at various installations will eventually reach the scientific literature. Work that has been completed includes studies of the direct impact of military activities on birds and the indirect effects that occur through habitat alteration. A source of information about the potential effects of maneuvers on birds is the literature on the effects of certain wildland recreation activities and certain natural-resource development and management activities. These include hiking, camping, off-road-vehicle events, helicopter flights, and traffic from construction—activities that produce disturbances similar to those induced by troop and mechanized movements. As with studies of the effects of actual military activities on birds, studies of the impact of recreational and natural-resource activities reveal direct influences on birds and indirect effects on birds that occur because of habitat modification. To date,

relatively few studies have targeted passerines; waterfowl, wading birds, shorebirds, and raptors have received the most attention. Although one cannot infer that responses by any one of these taxa would also be elicited in any of the other taxa, studies of these groups identify the array of possible disturbances birds may experience, and the possible responses they may exhibit.

Objectives

- To review reports about the direct and indirect (habitat) effects of actual military movements on avian behavior, reproduction, and community structure.
- To review reports about the direct and indirect (habitat) effects of certain recreational and natural-resource activities (i.e., those analogous to mechanized and nonmechanized troop movements) on avian behavior, reproduction, and community structure.
- To summarize the quality of existing information in terms of its value for establishing causal relations.
- To identify major knowledge gaps.

Approach

The literature was reviewed based on searches of the following databases: Expanded Academic Index, Biosis, Life Sciences Collection, Zoological Record, Ecological Abstracts, and on a search of Baylor University's main library, which is a depository for Government documents. The literature cited sections of much of the scientific literature reviewed provided additional leads on pertinent articles. To maintain a reasonable standard of accuracy, published peer-reviewed literature was used primarily. When publications in scientific journals resulted from work for the U.S. Department of the Army, the published papers rather than the associated Army final reports were reviewed.

2 Effects of Military Activities on Birds

This chapter summarizes reports about direct and indirect (habitat) effects of military activities on birds. Military activities include tank or tracked-vehicle movements, artillery fire, military helicopter movements, and troop encampments. Effects of super- and subsonic, fixed-winged aircraft are not addressed here. Only a few references that specifically addressed the effects of vehicle noise were found and are described. The emphasis of this chapter is whether there were impacts on avian behavior, reproduction, and community structure. Data for community structure may include species composition, diversity, richness, abundance, or biomass.

Direct Effects of Military Activities

Behavior

The effects of mechanized military activities on avian behavior vary. At Fort Sill, Oklahoma, wild turkeys (*Meleagris gallopavo*) and northern harriers (*Circus cyaneus*) roost successfully just outside a strafing area for the Air Force Reserve (Tennesen 1993). Yet, prairie falcons (*Falco mexicanus*) that hunt for ground squirrels on the Orchard Training Area in Idaho encounter tanks and artillery fire while hunting, and falcons on the training site have larger home ranges and rely less on ground squirrels than do prairie falcons that forage outside of the Orchard Training Area (Tennesen 1993). Andersen, Rongstad, and Mytton (1986) radio-equipped a red-tailed hawk (*Buteo jamaicensis*) on the Fort Carson Military Reservation (FCMR) in Colorado, a site used for tank maneuvers (involving up to 50 tanks at a time) and heavy artillery fire. In the absence of military activity, the telemetered hawk used a large part of the training area; but during times of maneuvers, the hawk was never detected in the training area. Instead, the bird exclusively used an area that was centered about 1.75 km away from the training area. This hawk returned to the maneuver site after training was completed.

Andersen, Rongstad, and Mytton (1990) studied the effects of military maneuvers on raptors at the Piñon Canyon Maneuver Site (PCMS) in Colorado. The maneuvers included helicopter activity, bivouacs for several hundred troops for 3

to 5 days, and traffic of military vehicles and troops. Red-tailed hawks that encountered military activity shifted the center of their home ranges farther than did red-tailed hawks that did not encounter military activity. One Swainson's hawk (*B. swainsoni*) and one ferruginous hawk (*B. regalis*) exposed to military disturbance left the training area and were not observed again until the following breeding season. For Swainson's hawks, ferruginous hawks, and golden eagles (*Aquila chrysaetos*) collectively, birds exposed to maneuver disturbance moved the center of their home ranges significantly more than did members of these species that did not experience this disturbance. After pooling data for all species studied, Andersen, Rongstad, and Mytton (1990) found that disturbed birds had larger home ranges and moved outside of their home ranges more frequently than did birds not disturbed by training activities. During maneuvers, some individuals used only the parts of their home range that were distant from the disturbances.

Andersen, Rongstad, and Mytton (1989) studied the effects of low-altitude helicopter overflights on nesting red-tailed hawks at the PCMS and the FCMR in Colorado. The PCMS had received little human activity and no helicopter activity until 1983, when the U.S. Department of the Army acquired it; however, the FCMR had experienced extensive low-level aircraft training since the late 1950s. Of 17 red-tailed hawks on PCMS, 9 (53 percent) were flushed from nests; only 1 of 12 (8 percent) on FCMR were flushed. Flushes were induced by a helicopter that directly approached the nest at 45 to 65 km/hr from 500 m away at 30 to 45 m above the ground. Behaviors elicited by helicopters were not significantly different between years (1984 and 1985) for either study site. Andersen, Rongstad, and Mytton (1989) reported data from Platt (1977) that gyrfalcons (*Falco rusticolus*) subjected to helicopter disturbance during the nesting period were less likely than undisturbed conspecifics to reuse the same nest site the following year.

Based on the information presented in this section, the direct effects of military activities on avian behavior appear to be species-specific and to depend on the history of military disturbance. Individuals in areas receiving such disturbance over extended time periods did not seem to be affected as much as individuals from areas in which military disturbance was relatively new. Some species may be capable of adapting to military disturbance via habituation or learned tolerance (Andersen, Rongstad, and Mytton 1989, Tennesen 1993). No studies were found for the direct effects of military maneuvers on behavior of passerines, waterfowl, or other avian taxa that use military installations. Similarly, no information was found about how troop movements per se (i.e., apart from vehicular travel) affect avian behavior.

Reproduction

Only one study was even close to a direct assessment of the effects of military maneuvers on avian reproduction. Andersen, Rongstad, and Mytton (1989) assessed the success of red-tailed hawk nests during each of 2 years; each nest was subjected to one breeding-season helicopter overflight each year. Success was examined again for 17 of these nests 1 year after all overflights were completed. During the first year (1984) of 2 years of overflights, all nests fledged at least one offspring. In 1985, 1 of 5 nests (20 percent) in a long-time military training area failed, and 1 of 7 nests (14 percent) at a maneuver site used just since 1983 failed. One year after all overflights, all five nests relocated in the long-time training area were successful, and 10 of 12 (83 percent) nests relocated in the more recent maneuver area were successful. One might expect responses by adults to helicopter disturbance to be more defensive as age of the young increases, but Andersen, Rongstad, and Mytton (1989) did not find an association between the degree of defensiveness near the nest and nestling age ($r = 0.105$, $n = 28$, $P > 0.60$). Although these authors did not detect a difference in reproductive success between the two military areas, they warned that individuals which have not experienced low-altitude aircraft disturbance may respond by leaving the nest unattended, abandoning it at critical times, or inadvertently knocking young or eggs out of the nest while flushing from the disturbance.

The lack of explicit information about how military activities actually influence avian reproduction makes it impossible to draw inferences about the impact of different types of maneuvers on various species. Nevertheless, the study by Andersen, Rongstad, and Mytton (1989) provides examples of possible results.

Community Structure

The direct effects of military activities on community structure were not the focus of the studies found. However, because of the behavior changes that have been documented at the level of individuals, one can hypothesize what impacts might accrue at the community level. For example, if raptors are displaced from areas by military activity (Tennesen 1993), prey (bird and mammal) populations in those areas may increase and influence other parts of the community (e.g., insects, vegetation) with which they interact. Displaced raptors may exhibit diet shifts (Tennesen 1993) that reflect the prey base of the locale to which they have been pushed by military disturbance. In these ways, competitive and predatory interactions, which in part determine the structure of avian communities, can be altered. Thus, it seems likely that disturbances induced by military activity may ripple through communities and affect the abundances of, and hence functional relations

among, many different bird species. Species-specific avoidance of military disturbance is common, and such responses may eventually generate communities dominated by species that tolerate the disturbances (Andersen, Rongstad, and Mytton 1989).

Indirect (Habitat) Effects of Military Activities

Behavior

Available information suggests that, at certain levels of disturbance, some species will abandon military bases because of habitat alteration and reduction. Encampments and mechanized maneuvers cause such habitat changes. Because the emphasis of associated references is on community structure, the work is discussed in "Community Structure." No articles were found that dealt explicitly with behavioral changes originating from military-induced habitat alterations.

Reproduction

Apparently no published information that specifically addresses avian reproduction in relation to habitat alterations caused by military maneuvers is available. But it is reasonable to expect reproduction to decline in areas subject to habitat disturbance from training because the changes would lead to direct displacement or local population reductions via habitat loss. Birds are known to respond to specific habitat stimuli at various spatial scales (e.g., Gutzwiller and Anderson 1987); so, even if only habitat structure (but not habitat amount or connectivity) was altered slightly, one would anticipate influences on site use and, hence, local reproductive activity.

Community Structure

Severinghaus and Severinghaus (1982—based on Severinghaus, Riggins, and Goran 1979, 1980; Severinghaus and Goran 1981; and Severinghaus et al. 1981) found that tracked vehicles at four maneuver sites in different parts of the United States altered breeding bird communities through habitat changes. Modifying factors included the nature of training, the amount of off-road activity, and environmental variables such as erodibility, climate, natural vegetation, and vegetative resiliency. Severinghaus and Severinghaus (1982) also identified five key processes through which habitat impacts affected bird communities: opening of the canopy, understory reduction, soil and duff scraping, food loss, and declines in plant productivity. Canopies are opened when vehicles knock down trees or injure them

to the extent that they later die. Large canopy trees also may be killed if their roots are damaged from soil compaction by vehicles. However, current training policies typically restrict destruction of trees during off-road vehicle maneuvers. Although some understory species may grow better with the additional sunlight and moisture that become available, there is more plant biomass lost through the death of large trees than is gained by growth of younger seral stages. Forest bird biomass declines as forest biomass declines. Elimination of canopy trees leads to more edge and field habitat, and the composition of the avian community changes accordingly.

The understory of habitats is reduced substantially by maneuvers because of repeated contact. Saplings, shrubs, and seedlings are damaged not only mechanically but also through soil compaction and erosion. Tracked vehicles, especially when they turn or pivot, break up the humus layer with their cleats and thereby enhance erosion of ground vegetation, duff, and topsoil. A number of woodland and edge birds depend on the understory for various resources throughout their annual cycle. Because some birds nest in ground cover, and many species obtain food at this stratum, such changes alter or decrease utility of ground cover for these species.

Food reduction occurs as a consequence of the three types of habitat change described here. As habitat is lost, so are primary and (in turn) secondary consumers. Small birds may be among the primary consumers in an area, and secondary consumers at a site would include insectivorous and carnivorous birds. Thus, habitat changes induced by military maneuvers may have cascading effects on avian trophic structure and community composition.

Even when the vertical layering or total extent of habitat is not altered by training activity, vegetation still may be degraded and lead to declines in plant productivity (e.g., vegetation that survives maneuvers is often less dense). The prime causes of productivity losses are believed to be soil compaction, the cutting and tearing action of cleats, and erosion.

Bird censuses at training sites and nearby control (little or no tracked-vehicle activity) sites during the breeding season (Severinghaus and Severinghaus 1982) suggested maneuver-induced changes in bird biomass and species diversity. At Fort Lewis, Washington, a prairie system that received relatively light traffic, bird biomass decreased 20.2 percent and species diversity decreased 50 percent. At Fort Polk, Louisiana, a forested site receiving light to moderate use, avian biomass increased 18.8 percent and diversity increased 16.7 percent, apparently because the closed canopy vegetation was opened and diversified by tracked-vehicle activity. Fort Hood, Texas, was used moderately for training activities; avian biomass

declined 48.6 percent and diversity dropped 18.8 percent. Sites at Fort Knox, Kentucky, were used heavily, but for different lengths of time. Sites that had been used for only 1 or 2 years exhibited a 55.3 percent decrease in avian biomass and a 52.6 percent decline in bird species diversity; sites that had been used for 35 years showed a 93.7 percent loss in biomass and a 94.8 percent reduction in diversity compared to control sites.

Severinghaus and Severinghaus (1982) noted that such changes can lead to species replacement. They found that some sensitive, secretive, and native species were replaced by exotic species, species tolerant of training activities, or both. Moreover, secretive species (ruby-throated hummingbird [*Archilochus colubris*], Swainson's thrush [*Catharus ustulatus*], veery [*C. fuscescens*], black-and-white warbler [*Mniotilta varia*], and rose-breasted grosbeak [*Pheucticus ludovicianus*]) were detected only on control sites. Less secretive species (northern bobwhite [*Colinus virginianus*], yellow-rumped warbler [*Dendroica coronata*], brown-headed cowbird [*Molothrus ater*], northern cardinal [*Cardinalis cardinalis*], and white-throated sparrow [*Zonotrichia albicollis*]) were detected on test and control sites. Species tolerant of training disturbances (rock dove [*Columba livia*], horned lark [*Eremophila alpestris*], northern mockingbird [*Mimus polyglottos*], and European starling [*Sturnus vulgaris*]) were found only at disturbed sites.

Diersing and Severinghaus (1984) analyzed the effects of tracked vehicles on breeding birds at Fort Carson, Colorado. For prairie and pinyon-juniper (*Pinus-Juniperus*) habitats separately, they compared soil, vegetation, and bird data from an impacted (test) site to those from a site that had received relatively little tracked-vehicle activity (control site). On the prairie test site, tracked-vehicle activity reduced water infiltration, increased soil erosion, reduced grass cover, and increased 'weedy' forbs. For the prairie sites, the abundances of mourning doves (*Zenaida macroura*), horned larks, western meadowlarks (*Sturnella neglecta*), and lark sparrows (*Chondestes grammacus*) did not differ significantly between the test and control sites. Total avian biomass on both prairie sites was essentially the same; however, biomass of the seed-eating, open-field guild (comprised of lark sparrow and lark bunting [*Calamospiza melanocorys*]) was higher on the test site than on the control site, and biomass for the omnivorous, open-field guild (western meadowlark) was lower on the test site than on the control site. Diersing and Severinghaus (1984) attributed this decline in western meadowlarks to a decrease in total grass cover caused by tracked-vehicle maneuvers on the test site.

For the pinyon-juniper test site at Fort Carson, tracked-vehicle activity reduced water infiltration, increased erosion, reduced tree canopy cover 55 percent, and reduced shrub cover 85 percent. There were eight pinyon-juniper bird species

whose numbers were comparable between the control and test sites: chipping sparrow (*Spizella passerina*), rufous-sided towhee (*Pipilo erythrophthalmus*), plain titmouse (*Parus inornatus*), black-headed grosbeak (*Pheucticus melanocephalus*), ash-throated flycatcher (*Myiarchus cinerascens*), gray flycatcher (*Empidonax wrightii*), solitary vireo (*Vireo solitarius*), and lark sparrow. But broad-tailed hummingbirds (*Selasphorus platycercus*), western wood-pewees (*Contopus sordidulus*), and pinyon jays (*Gymnorhinus cyanocephalus*) occurred only on the test site; and the scrub jay (*Aphelocoma coerulescens*), red-breasted nuthatch (*Sitta canadensis*), mountain bluebird (*Sialia currucoides*), warbling vireo (*Vireo gilvus*), brown-headed cowbird, and western tanager (*Piranga ludoviciana*) were detected only on the control site. Total avian biomass was similar between the test and control site. However, biomass for the open-field and edge guilds (rufous-sided towhee, lark sparrow, chipping sparrow) was considerably higher on the test site than on the control site, and biomass for the woodland guild (ash-throated flycatcher, gray flycatcher, black-headed grosbeak, western wood-pewee, western tanager) was appreciably lower on the test site than on the control site. Diersing and Severinghaus (1984) attributed these differences to opening of the woodlands by tracked-vehicle maneuvers. They concluded that woodland bird species were being replaced by edge and open-field species on the test site because of habitat impacts.

Krzysik (1984) examined the effects of tracked vehicles and bivouacs on vegetation and associated bird communities (primarily breeding birds) at Fort Irwin, California. Sites representing four relative levels of disturbance were studied: control sites (not used for war games), and lightly impacted, moderately impacted, and severely impacted sites. The dominant woody species, creosote bush (*Larrea tridentata*) and burroweed (*Ambrosia dumosa*), had lower densities, smaller diameters, and were shorter at training sites than at control sites. Comparisons between training areas and control sites indicated that, on the ground surface, training activities significantly increased the percentage of small sand particles (< 3 mm diameter) and significantly decreased the percentage of larger sand particles (3 mm to < 1 cm) and gravel (1 to 8 cm). Compared to control sites, the percentage of bare ground was significantly higher and forb cover was significantly lower on training sites.

Horned larks used all sites similarly, even though there were large differences in vegetation and soil substrate particle sizes among sites. Black-throated sparrows (*Amphispiza bilineata*) used the moderately impacted site and its associated control site similarly, but there was a significant drop in numbers for this species on the severely impacted area. Brewer's sparrows (*Spizella breweri*), sage sparrows (*Amphispiza belli*), western meadowlarks, and one breeding pair of LeConte's

thrasher (*Toxostoma lecontei*) were detected just on the lightly impacted or control (unimpacted) sites. Migrant and transient white-crowned sparrows (*Zonotrichia leucophrys*), chipping sparrows, and LeConte's thrashers used moderately impacted areas, but they were never detected at the severely impacted maneuver area.

Avian biomass did not differ between control and lightly impacted areas, but it was significantly lower on moderately and severely impacted sites relative to lightly disturbed or control sites. The differences were attributable to a total loss of species that were adversely affected by the associated changes in vegetation. In general, the structure of avian communities was tied closely to shrub cover, as expected in shrubsteppe systems. Krzysik (1984) also noted that the bird-habitat relations he demonstrated, as well as the bird-biomass differences between impacted and unimpacted sites that he detected, were consistent with the bird species' life-history features and habitat needs.

Three papers (Lathrop 1983a, Wilson 1988, Forbes 1992) were found that examined the impact of military maneuvers or tracked vehicles on vegetation only; that is, the investigators did not determine what community-level effects there might have been on birds. Discussion of these studies is included here because of the well-known association between habitat structure and avian-community structure. Habitat alterations that modify important vegetative components for a given species are likely to influence at least site use, if not other metrics, for that species.

Lathrop (1983a) studied the effects of military maneuvers on perennial vegetation at Camps Ibis and Essex in the eastern Mojave Desert in California. Both areas were used heavily from 1938 to 1942. To assess how long the effects from such disturbances may last, in 1978 Lathrop (1983a) examined how the vegetation had recovered. The impacts of the maneuvers were determined for tank areas, tent areas, and roadways relative to respective controls (nearby undisturbed sites). Plant species richness for dominant perennials was higher on disturbed areas as a group (10 species) than on control sites (4 species) 36 years after the maneuvers, and Lathrop (1983a) noted that this increase may lead to instability of the system, depending on species composition. Perennial plant density (2,338/ha) and cover (8.2 percent) on control sites was higher than those for tent areas (1,699/ha, 4.2 percent), tank areas (1,077/ha, 2.9 percent), and roadways (782/ha, 1.4 percent) after 36 years. During this period, percentages of recovery to control levels of density and cover were highest for tent areas (60 percent), lower for tank areas (39 percent), and least for roadways (23 percent). Lathrop (1983a) estimated that the average length of time it would take for density and cover in training areas to recover to the levels of those in control areas was about 50 years for tent areas, 70 years for tank areas, and 160 years for roadways. He noted that, for percentage composition and

community vigor to return to premaneuver levels, multiples of these periods would be needed, if recovery occurred at all. Vegetation in arid lands is clearly susceptible to damage by training maneuvers, and birds that rely strongly on the structure and species composition of these habitats are likely to be influenced in important ways (including altered community structure) for long periods of time.

Wilson (1988) assessed the effects of tank movements on prairie vegetation at Canadian Forces Base-Shilo in Manitoba, Canada. On experimental plots that received tank traffic only occasionally, regularly during both spring and summer and regularly during spring only, nonnative plant species (*Salsola pestifera*, *Chenopodium album*, and *Melilotus alba*) became established. No exotic species invaded plots when they received summer driving only, or no driving at all. The frequency of sampling points with bare ground was positively correlated with the number of tank passes through experimental plots for both spring and summer tank traffic, spring only traffic, and summer only traffic. The number of tank passes needed to generate a particular frequency of bare ground was significantly higher for summer only (July and August) traffic than for spring and summer (May to August) driving. Wilson (1988) noted that, if tank maneuvers were delayed until after June—the period of intense growth in this system—prairie vegetation might be able to support maneuver activities without damage. He suggested that, if tank activity was restricted to the period from July to spring thaw, the capacity of the prairie to sustain training maneuvers without damage would be increased by 400 percent. The significance of this for prairie birds at such sites is that the integrity of their habitat, from species composition to vertical and horizontal structure, might be preserved if tank maneuvers were timed appropriately during the year. Of course, if their habitats were maintained, it is more likely that birds would be able to persist on training sites.

Wilson (1988) was careful to note that, although his results are probably generally applicable to different tracked vehicles driving on prairie,

- vehicle type may influence impacts
- his results were for straight-driving (but not pivoting) tanks that drove across prairie vegetation evenly in time and space
- his results applied to the type of prairie vegetation with which he experimented.

Wilson (1988) found that tank traffic appears to reduce shading effects from tall species, thereby enabling shorter species to increase in abundance. One long-term effect of this tank-induced process may be a compositional change in which the smaller plant species become dominant. To the extent that bird species respond

directly or indirectly to such changes, their use of sites (and ultimately community structure) will be altered.

Some environments are extremely susceptible to damage by tracked vehicles; the high-arctic tundra meadows studied by Forbes (1992) are good examples. Although training by military tracked vehicles currently is very limited in arctic regions, Forbes (1992) evaluated effects from use of industrial tracked vehicles in these areas. Forbes (1992) found that plant species richness was consistently and significantly reduced for both vascular and cryptogamic species by several different low-level disturbances from tracked vehicles. In 88 percent of the stands he studied, the biomass of all vascular plants was reduced significantly by damage from tracked vehicles. Woody species were damaged the most. At sites that received multiple vehicle passes, dicotyledon establishment was severely limited, even 18 to 20 years after the last disturbance. Species that had colonized damaged sites were slow-growing, and Forbes (1992) did not expect predisturbance biomass levels to be achieved in the foreseeable future. Bared surfaces more than about 1 m wide were invaded from their edges inward; only grasses atypical of undisturbed tundra meadows were able to colonize the center of such areas. One would expect bird species that rely on such vegetation for food, shelter, or nest sites to be influenced negatively, both in the short term and (because of limited recovery potential) in the long term.

The information in this chapter on indirect (habitat) effects indicates that:

- vegetative structure, floristic composition, and even the capacity for succession can be altered in a number of obvious and subtle ways by military maneuvers
- avian density, richness, species composition, and biomass can be influenced by such changes because birds respond to specific vegetative stimuli at several spatial scales
- changes in avian density, richness, species composition, and biomass necessarily involve site abandonment or colonization, so maneuver-induced behavioral responses are linked inextricably with, indeed result in, new distributions and altered community structure
- high levels of habitat disturbance tend to reduce avian biomass and displace sensitive, secretive species
- habitats severely altered or degraded by training maneuvers tend to support greater numbers of exotic or disturbance-tolerant plant and bird species
- studies that have focused on impacts to plants provide valuable information for predicting changes that might occur in associated bird communities
- the seasonal timing of military activity may significantly influence its impact on vegetation and, hence, associated avifauna.

3 Effects on Birds From Recreational Disturbance and Natural-Resource Development and Management

This chapter summarizes what has been reported about direct and indirect (habitat) effects of disturbances comparable to maneuvers, such as some recreational and natural-resource development and management activities. The emphasis in this chapter is the same as in Chapter 2—were there impacts on avian behavior, reproduction, and community structure? Data for community structure may include species composition, diversity, richness, abundance, or biomass.

Direct Effects From Recreational Disturbance and Natural-Resource Development and Management

This section discusses the reported effects of certain recreational and natural-resource activities on birds. Only wildland activities with actions or effects comparable to those of troop movements, bivouacs, or wheeled vehicles will be discussed. These activities include hiking, camping, vehicle movements on and off roads, picnicking, and helicopter flights. The effects of other activities—including fishing, sailing, boating, hunting, wildlife photography, and wildlife viewing—will not be reviewed. Water-based recreation is too unlike terrestrial military maneuvers to be pertinent. Hunting will not be addressed here because birds are not shot during maneuvers, and the effects of military noise on wildlife is reviewed in Larkin, Pater, and Tazik (1996). In seeking their subjects, wildlife photographers and wildlife viewers often operate alone or with few other people; they approach wildlife directly, closely, and repeatedly, and they often remain near wildlife for extended periods (Boyle and Samson 1985). Military group size and troop behavior in relation to birds are not comparable to group size and behavior for wildlife photographers and viewers.

A number of final reports, articles in obscure foreign journals, symposia proceedings, pamphlets, and other materials with limited accessibility were summarized briefly in annotated bibliographies. Information from these annotations is incorporated into this literature review; however, because the details

from these annotated studies were not available, information about them is not included in the discussion of the quality of existing information (see Chapter 4).

Behavior

Disturbances from recreation and natural-resource development and management can influence avian behavior in a number of ways. This section discusses effects from helicopters, wheeled vehicles, roads, camping, picnicking, and hiking. Several references in this section deal with natural-resource development (e.g., oil-well construction, heavy machinery operation) or management (e.g., avian surveys from helicopters, hazing geese with a helicopter to redistribute them), but most citations address recreational disturbances.

Through an annotated bibliography, Dahlgren and Korschgen (1992) summarized literature on the effects of human disturbance on waterfowl. They identified eight references that involved helicopter disturbance similar to what might occur during troop movements; the recorded impacts on behavior are described here. Berger (1977) found that snow geese (*Chen caerulescens*) on the staging grounds exhibited signs of being disturbed by flushing at an average distance of 2.7 km from approaching helicopters. Eurasian widgeons (*Anas penelope*) were disturbed by low-flying helicopters, which altered their time budgets and significantly reduced their feeding time (Campredon 1981). Davis and Wiseley (1974) found that a helicopter disrupted the feeding behavior of snow geese and decreased their feeding time by 9.5 percent. Helicopters altered the use of particular feeding areas and flight activity in brants (*Branta bernicla*); helicopters flying below 300 m often displaced flocks from near-shore habitats and forced them to use the ocean (Henry 1980). Molting geese seem to be particularly susceptible to helicopter disturbance. Pink-footed geese (*Anser brachyrhynchus*) reacted to flying helicopters when they were still 10 km away by swimming to open water; and, when the approaching helicopter was 4 km away, the geese clumped together in panic (Madsen 1984). Barnacle geese (*Branta leucopsis*) did not react to a helicopter 4 km away, but they did become alarmed when a helicopter was within 1 to 2 km (Madsen 1984). Thus, considerable interspecific differences in behavior existed among molting geese (Madsen 1984). Owen (1973) reported that wintering geese were controlled more by disturbance than food availability, and that helicopters constituted a serious source of disturbance in grasslands. Helicopters were used to redistribute Canada geese (*Branta canadensis*) away from Horicon National Wildlife Refuge and adjacent private croplands. Geese flushed up to 2 km away from a low-flying helicopter operated during daylight hours, but the geese returned soon after sunset when the helicopter could no longer be used (Rusch et al. 1985). Species that

responded to helicopters several kilometers away (hence out of sight) evidently were responding to the noise from the helicopter.

Noise from helicopters simulating oil-exploration activities caused brant, Canada geese, and emperor geese (*Chen canagica*) to interrupt their feeding and flush. Ward and Stehn (1989) calculated that each such additional disturbance during a 54-day fall staging period would reduce an individual's total weight gain by 7.5 g, which is equivalent to the amount of energy needed for 53 minutes, or 73 km, of migratory flight. Brant responded similarly at all helicopter altitudes up to 610 m.

Kushlan (1979) compared the effects of helicopter overflights to those of a small plane on colonial-nesting wading birds (great egret [*Casmerodius albus*], snowy egret [*Egretta thula*], Louisiana heron [*Hydranassa tricolor*], wood stork [*Mycteria americana*]). Prior to Kushlan's investigation in 1977 (Kushlan 1979), planes had been used in his study area to study nesting colonies for two decades, apparently without appreciable effects on the birds. Accordingly, Kushlan (1979) considered disturbance from a small plane to be a control for the helicopter activity; disturbances from helicopters occurred at 60 m and 120 m above the ground. Of 220 observations, almost 75 percent indicated no reaction by the birds, and 90 percent of the observations indicated birds either did not respond to the helicopter or simply looked up at it. All individuals that abandoned their nests returned within 5 minutes; 11 individuals that left their nests returned within an average of 1.4 minutes. Compared to impacts of fixed-wing aircraft, most helicopter overflights caused the same or fewer effects. Helicopter activity had no apparent effect on: nesting brown pelicans (*Pelicanus occidentalis*); double-crested cormorants (*Phalacrocorax auritus*) in tree tops; white ibis (*Eudocimus albus*), wood storks, and great blue herons (*Ardea herodias*) in trees; and laughing gulls (*Larus atracilla*) on the ground.

In northwestern Washington, Watson (1993) found that helicopter approaches caused ≥ 40 percent of nesting bald eagles (*Haliaeetus leucocephalus*) to become alert or flush; these responses were elicited at distances $< 3,050$ m. Of 270 perched eagles, 53 percent were disturbed. Ninety-seven of these individuals were flushed, and 45 were agitated without being flushed. Eagles exhibited higher rates of disturbances when nests did not contain young and when the helicopter hovered compared to when it approached the nest. Eagles that were feeding young seemed to ignore the helicopter.

In a study of tree-nesting ospreys (*Pandion haliaetus*), Carrier and Melquist (1976) used a helicopter in May and again in July to identify active nests and determine clutch size, hatching success, and number of nestlings. There was little evidence

that ospreys were sensitive to helicopter disturbance. For example, although the May survey occurred before some individuals had laid eggs—a particularly sensitive period for most birds—none of the nests without eggs was abandoned. When disturbed by a helicopter to within 50 m, incubating adults typically stood then flushed from the nest; the nest cups were deep enough that, coupled with this standing behavior, no eggs were pushed out of the nest. Several incubating adults could not be chased off the nests even with closer helicopter approaches. The air turbulence caused by the helicopter did not flush adults or alter nest structure. Ospreys were never startled by approaching helicopters; consequently, no eggs were broken or dislodged from the nest because of hasty departures by adults. After flushing from the helicopter, ospreys usually returned to their nests within 1 minute, and there was no obvious impact on nesting effort (Carrier and Melquist 1976). Overflights later in the breeding season, in addition to adult alarm calls, caused nestlings to lie in the nest without moving. Thus, no birds fledged prematurely as a result of being pushed out of the nest by air turbulence from the helicopter.

In their annotated bibliography, Dahlgren and Korschgen (1992) summarized data on the effects of roads and traffic on waterfowl behavior. This information, which is described in this paragraph, is pertinent because disturbances associated with roads and traffic in wildlands are analogous to disturbances from roads and traffic at maneuver sites. Mooij (1982) reported the following behavior patterns for foraging geese at varying distances from roads: geese occasionally foraged within 250 m from roads, until they were disturbed; at 250 to 350 m from a road, geese fed irregularly; at 350 to 450 m, geese fed frequently; they fed regularly at 450 to 550 m; and at areas 550 m or more from roads, geese foraged intensively. Wheeled-vehicle traffic can disrupt Canada geese brood units during the initial 3 to 4 weeks of life. Sherwood (1965) found that vehicles driving on dikes at Seney National Wildlife Refuge in Michigan caused broods to panic and disperse. Most goslings lost in or slowed by thick vegetation were left behind by parents that swam away from the vehicles. Flocks of brant gradually became used to construction and farm machinery that traveled along a road each day, and they foraged within 10 m of the road (Williams and Forbes 1980). These geese often permitted humans to approach to within 50 m before they flushed. However, Eurasian widgeons typically fed much farther away from the road. Only when traffic was less frequent, as on weekends, did widgeons feed near the road (Williams and Forbes 1980). Pink-footed geese fed and loafed in the center of large fields, usually 300 m or more from roads and vehicles (Fruzinski 1977). Wintering mallards exhibited changes in habitat use, daily activity budgets, and food habits in part because of vehicular traffic (Heitmeyer 1985). Fall feeding by pink-footed geese was not near roads, but graylag geese (*Anser anser*) preferred to feed in fields close to roads. Graylag geese

tolerated less distance between themselves and vehicles (100 to 300 m) than did pink-footed geese (300 to 600 m) (Madsen 1985a). Roads carrying more than 20 cars per day disturbed pink-footed geese from 500 m away. Small roads transporting 0 to 10 cars per day also reduced field use by these geese (Madsen 1985b).

Disturbances associated with oil-well construction—noise, traffic from trucks and heavy equipment, and lights at night—apparently caused breeding wading birds, laughing gulls, and Forster's terns (*Sterna forsteri*) to reduce their use of a nearby colony (Mueller and Glass 1988). The authors surmised that the disturbances altered site use because they occurred when birds were just beginning to choose nest sites and establish territories. Baydack and Hein (1987) experimentally disturbed leks used by sharp-tailed grouse (*Tympanuchus phasianellus*) with a parked vehicle (engine on or off). They found no difference in male use of leks due to the disturbance, but females were never detected on leks during disturbances. Staging greater snow geese (*Chen caerulescens atlantica*) were flushed by the presence or rapid movements of cars, trucks, or agricultural equipment (Bélanger and Bédard 1989). Geese flushing from each such disturbance spent an average of 31 to 32 seconds in flight, and 69 to 103 seconds elapsed before they resumed feeding. Nesting trumpeter swans (*Cygnus buccinator*) remained alert in the presence of loud gravel trucks on a nearby road; they exhibited alertness to passenger vehicles only when drivers stopped or honked their horns (Henson and Grant 1991). In a study of waterbird responses to experimental disturbances from a vehicle at the J.N. "Ding" Darling National Wildlife Refuge, Klein (1993) reported that many species either did not respond or simply looked up at the vehicle when it passed by but did not stop, or when it stopped within view of the bird but no one stepped out of the vehicle. Flemming et al. (1988) found that approaching vehicles did not affect adult or chick behavior in piping plovers (*Charadrius melodus*). Managers at 16 national wildlife refuges in the mid-Atlantic states indicated that driving on beaches by visitors accounted for about 21 percent of all impact situations for birds; impacts included reduced use of the refuge, reduced habitat use, and aberrant behavior or stress (Purdy et al. 1987). Four of seven shorebird species were displaced from roost sites or entire beaches during fall migration because of wheeled-vehicle traffic (Pfister, Harrington, and Lavine 1992). Overall, wheeled vehicles and roads may or may not be disruptive to birds, depending on a species' sensitivity, the seasonal timing and daily regularity of disturbances, and the proximity of disturbances.

The impact on behavior from wildland campers, picnickers, and hikers will be described next. Only those situations in which disturbances are repeated over time and in which many different persons are involved—as might occur during non-mechanized movements of many troops during a training session or a series of

sessions—will be considered. Influences from investigators or from the occasional hiker, camper, or picnicker are not summarized (here or elsewhere in this review) because such sources of disturbance are too different from military troop movements to be relevant.

An annotated bibliography by Boyle and Samson (1983) summarized some inaccessible writings germane to this section of the review. The direct or potential effects of campers, picnickers, and hikers on avian behavior reported in these articles will be described. Scott-Williams (1967) noted that birds' behavior was altered at roadside turnouts and parking areas by people who offered them food. Backcountry hiking had the potential to disturb California condors (*Gymnogyps californianus*) (Mallette 1978). Disturbances from resource development and recreational activities that occurred before eggs hatched had the potential to cause nest desertion by ferruginous hawks (Snow 1974). Picnickers can prevent terns from incubating eggs and feeding young (Gochfeld 1976). Telemetered wild turkeys avoided hiking trails and did not use habitat within 1 km of campgrounds (Wright and Speake 1975).

Nesting trumpeter swans immediately became aware of nearby people, especially if the people made noise or were in view (Henson and Grant 1991). Three of six instances of pedestrian disturbance during incubation caused swans to leave their nests for 22, 41, and 90 minutes. Three other disturbances occurred after broods left the nest, and in all cases broods were repelled by people, swam to the opposite side of the wetland, and hid in emergent vegetation (Henson and Grant 1991). During four prelaying disturbances, adult swans moved away from disturbances and were attentive as long as people were still in sight. Breeding common ravens (*Corvus corax*) did not abandon nests, even though some were visited by groups of up to 20 people at a time. Many ravens completed their breeding activities in relatively close association with people, and Hooper (1977) thought they relied on humans for an important amount of their food. Hunt (1972) reported that picnickers displaced herring gulls (*Larus argentatus*) from their nests, causing their eggs to be addled by the sun. When approaching people were as far away as 210 m, piping plovers flushed from their nests or broods, although adults usually did not flush in response to people until they were within 40 m. Pedestrians within 160 m caused piping plover chicks to feed and brood less frequently and exhibit vigilance and sitting more often (Flemming et al. 1988). During the preincubation period, golden plovers (*Pluvialis apricaria*) flushed from hikers who were within 200 m (Yalden and Yalden 1990). After being flushed during incubation, birds took significantly longer to return to their nests when people remained nearby. Adult golden plovers spent roughly 11 percent of their time (and 15 percent more energy) during the chick-guarding period flying away from hikers. In response to alarm

calls from their parents, chicks hid and were neither fed nor brooded. Adults that led their young to less-intruded areas experienced territorial conflicts with neighboring conspecifics (Yalden and Yalden 1990).

Brown pelicans left their nests in response to hikers who approached or visited the nesting colony. Their chicks, if less than 3 weeks old, were injured or killed by avian predators that took advantage of them after their parents had fled (Anderson and Keith 1980). Nesting bald eagles responded to 72 percent of pedestrian disturbances, and their median response duration was 8 minutes; responses included alertness, flight, and departure (Grubb and King 1991). Disturbance to young eider (*Somateria mollissima*) ducklings from hikers increased by fourfold the number of predators these ducklings encountered during a 5-minute period following the disturbance (Keller 1991). Hand (1980) observed a natural history tour group of approximately 75 people who had stopped for about 3 hours along a beach used by nesting western gulls (*Larus occidentalis*). Gulls flushed from their nests as members of the group approached, but they returned as long as people moved away. However, many gulls were kept off their nests for extended periods because tour members would follow each other at intervals, and each nearby gull reacted to the approach, pause, and passing of each person. These events occurred during mid-afternoon, and Hand (1980) indicated such repeated disturbance during this time of the day would hamper the adults' ability to regulate egg temperatures—a potentially fatal effect for developing embryos.

At two freshwater ponds, Burger (1981) studied the effects of hikers on roosting waterbirds and found that: gulls and terns flushed, but soon returned to where they had been; ducks typically flushed and landed in the middle of the ponds; and herons, egrets, and shorebirds (apparently disturbed the most) all left the ponds for distant marshes. On the northern Chesapeake Bay, bald eagles were located significantly less often than expected on segments of the shoreline being used by pedestrians (Buehler et al. 1991). Up to 50 percent of disturbances to shorebirds were caused by people walking along beaches, and birds were most disturbed during peak spring and fall staging periods when they foraged on beaches (Burger 1986). Shorebirds that responded to hikers stopped feeding and then either flew up and quickly landed near the same spot, or abandoned the site. Visitors exploring refuges on foot were deemed responsible for about 48 percent of all adverse effects on wildlife, primarily birds (Purdy et al. 1987); 55 percent of the impacts of exploring were reduced refuge use, reduced habitat use, and aberrant behavior or stress. No studies were found evaluating effects of nocturnal disturbance by humans. In general, campers, picnickers, and hikers usually affect avian behavior adversely; the principal impacts are changes in habitat use and reduced time available for incubation, brooding, feeding, and roosting.

Reproduction

Wheeled vehicles, roads, camping, picnicking, and hiking have all been associated with declines in avian reproduction. In their annotated bibliographies, Dahlgren and Korschgen (1992) and Boyle and Samson (1983) each identified one reference that involved wheeled-vehicle or road impacts on avian reproduction. Penny (1971) reported direct destruction of gallinaceous upland gamebird nests by off-road vehicles; Smith (1971) noted that road construction directly destroyed nests of northern pintails (*Anas acuta*) and mallards (*A. platyrhynchos*).

In a survey of 16 refuges, Purdy et al. (1987) reported that lowered productivity resulted from 26 percent of the impacts to wildlife (primarily birds) from driving on beaches; 50 percent of the impacts due to driving on roads in refuges led to reduced productivity. Melvin, Griffin, and MacIvor (1991) reported that vehicles on beaches can crush piping plover eggs and chicks; some unfledged chicks do not run from approaching vehicles. That vehicles significantly influence piping plover reproduction is evidenced by the results of beach closures to off-road vehicles: higher numbers of breeding pairs, higher productivity, and nesting in some areas that were not used before due to vehicle traffic (Melvin, Griffin, and MacIvor 1991). American kestrels (*Falco sparverius*) nesting in boxes attached to sign posts along I-35 in central Iowa had breeding metrics (nest box occupancy [45 percent], clutch size [4.8], nesting success [69 percent], hatching success [62 percent], fledging success [91 percent], brood size [3.1], and fledglings per brood [2.9]) that were similar to those for American kestrels using nest boxes not in close proximity to the constant noise and traffic of an interstate highway (Varland and Loughin 1993). Of 61 fledglings radio-marked by Varland and Loughin (1993), only two died because they were struck by vehicles along the interstate.

The proportions of bald eagle nests that were successful and unsuccessful were not associated with the proximity of nests (< 500 m or > 500 m) to disturbances from traffic, roads, or machinery (Fraser, Frenzel, and Mathisen 1985). Ferruginous hawks deserted three of eight nests that were repeatedly approached on a daily basis with a vehicle (White and Thurow 1985). The three nests were abandoned after six to eight vehicle disturbances; successful nests incurred 24 to 28 vehicle disturbances. With respect to the proximity of roads, however, ferruginous hawk nest location did not differ from that of random points. There was no relation between number of eggs in nests and whether or not birds deserted their nests (White and Thurow 1985). Despite noise from cement trucks that passed at least twice per day within 31 m of a northern goshawk (*Accipiter gentilis*) nest during construction of a house, four young fledged from the nest; the adults apparently habituated to, or at least learned to tolerate, the truck disturbance (Lee 1981). In

general, vehicles and roads may or may not affect reproduction, depending on the species and the specific nature and context of the disturbance.

Disturbance from campers caused peregrine falcons (*Falco peregrinus*) to abandon eyries (Herren 1969), it induced ospreys to abandon a nest and eggs (Garber 1972), and it contributed to declines in common loon (*Gavia immer*) reproduction (McIntyre 1979) (all three of these references are summarized in the annotated bibliography by Boyle and Samson 1983). In a study of herring gulls, Hunt (1972) found that disturbances from picnickers did not influence success rates for raising chicks.

Although great blue herons were sensitive to disturbance from hikers during the entire breeding season, no nests were lost because of hikers (Graul 1981, cited in Boyle and Samson 1983). As a result of disturbance from hikers and tour groups, brown pelican productivity (young fledged per nest built) was reduced by 89 percent, 52 percent, and 100 percent in 1971, 1972, and 1974, respectively (Anderson and Keith 1980). Impacts on productivity were exhibited primarily by immediate loss of pelican eggs and chicks to predation by western gulls following displacement of adult pelicans from their nests by people. Hooper (1977) found that a pair of common ravens fledged two young from a nest that was visited repeatedly by humans, including on one occasion a group of approximately 20 people.

Picozzi (1971) counted the number of red grouse (*Lagopus lagopus*) chicks in areas in which hikers were restricted to public rights-of-way and in areas that permitted hikers to walk over moorland areas away from public rights-of-way (unrestricted access). For a 3-year period, there was no difference in chick numbers between the two types of areas. Picozzi (1971) found that, during July and August (principal months of disturbance) in unrestricted-access areas, only 5 percent of the hikers strayed from rights-of-way. Apparently, a slight increase in disturbance from hikers, as represented by disturbance in the unrestricted- versus restricted-access sites, was not enough to influence chick numbers. Watson (1988) did not detect a significant correlation between the number of young dotterel (*Charadrius morinellus*) per adult and the number of hikers during the breeding season. He attributed this lack of impact to dotterel behavior. Specifically, adults incubating eggs or brooding small chicks did not move or flush until a person almost stepped on them. Such behavior in the presence of hikers implies dotterel are not too sensitive to this form of disturbance. Adverse physiological (hence inconspicuous) reactions to hikers may have occurred in dotterel, but there were no apparent effects of such responses on the number of dotterel chicks per adult. Campers, picnickers, and hikers—whose activities are analogous to those of military troops at localized encampments and during foot travel—can directly reduce reproduction

for species that are sensitive to (unable to tolerate or habituate to) these forms of disturbance.

Community Structure

Recreational disturbances similar to military troop movements and encampments, such as hiking, camping, and picnicking, can directly influence avian community structure by altering predator-prey relations and displacing species (Gutzwiller 1995). Trophic structure in avian communities can be influenced when normal predator-prey relations are altered. For example, hikers and tour groups tend to exacerbate predation by Heermann's gull (*Larus heermanni*) on young Heermann's gulls, elegant terns (*Thalasseus elegans*), and royal terns (*T. maximus*) (Anderson and Keith 1980). Double-crested cormorants (*Phalacrocorax auritus*) flushed from approaching hikers; before they returned to their nests, herring gulls ate undefended cormorant eggs and chicks (Kury and Gochfeld 1975). In contrast to disturbed colonies, levels of predation in undisturbed colonies typically have negligible effects on species composition, abundances, or the structuring force of predation. Such increases in predation caused by hikers can directly alter trophic structure and the relative dominance of species in communities.

Hikers, campers, and picnickers also can influence species richness, abundance, and composition by displacing sensitive species. For instance, densities for 8 of 13 breeding bird species were negatively associated with the intensity of recreational activity by park visitors, including hikers (van der Zande et al. 1984). Each species had its own level of sensitivity to human disturbance. Visitor disturbance also affected the presence or absence of five common species (van der Zande et al. 1984). Through these effects, hikers influenced species evenness, richness, and composition. Walkers using shoreline habitats contributed to declines in numbers of 11 of 12 species; lower abundances were associated with intensities of activity that involved from 8 to 37 people per hectare (maximum number of people present simultaneously) (van der Zande and Vos 1984). Depending on the interspecific interactions uncoupled or the species lost because of human-induced displacement, the presence or abundance of other species may be affected as well. By displacing predators, for example, humans may affect the abundance of other food-chain members (Hammit and Cole 1987, p 88). No other references were found that dealt with direct effects on community structure from disturbances comparable to troop movements and bivouacs.

The information presented in this section on direct effects from recreational disturbance and natural-resource development and management indicates that there is strong potential for adverse effects from comparable maneuver-caused disturbances.

As illustrated in the literature, helicopters, wheeled vehicles, roads, hikers, campers, and picnickers—all of which induce disturbances analogous to those from military troop maneuvers—can have detrimental effects on behavior, reproduction, and community structure. The literature also reveals that there is variation within and among species in their reactions to such perturbations. Not all species or individuals responded negatively to certain disturbances. Such varied responses are commonly reported in the recreation-impact literature and seem to arise from differences in the actual settings in which disturbances occur, differences among individuals and species in their exposure to and experiences with people, or both (Gutzwiller et al. 1994). In short, the effects of a variety of maneuver-like recreational disturbances seem to be context-specific (Gutzwiller 1993). Of course, at some high intensity of disturbance, most or all individuals and species may react in a consistent manner. As far as is known, no one has uncovered principles that can be used to predict avian responses to a variety of maneuver-like recreational disturbances under various conditions.

Indirect (Habitat) Effects of Recreational Disturbance

Off-road-vehicle (ORV) enthusiasts and campers can generate habitat alterations similar to those caused by wheeled vehicles and encampments during military training maneuvers. The most obvious results are habitat loss and degradation. These impacts, in turn, may influence birds because birds depend significantly on habitat quantity and quality. Thus, knowledge about ORV and camper impacts on habitats should improve the understanding of the potential for comparable military activities to influence birds via altered habitats.

Behavior

No studies were found that explicitly dealt with behaviors elicited by recreation-induced habitat change. ORV- and camper-caused habitat changes undoubtedly have behavioral effects on birds, but the literature reviewed documented only the results of those behaviors, such as changes in community structure following apparent site abandonment (see "Community Structure"). No studies that examined the series of behavioral reactions that lead to such consequences were found.

Reproduction

No studies were found that explicitly examined how ORV- or camper-induced habitat changes influenced production or survival of young. Clearly, if birds'

habitats are being destroyed or degraded in an area, their reproductive success is likely to suffer in that area. Several studies dealt with breeding bird richness, abundance, and composition; but the focus of those studies was on the community, not the number of eggs, nestlings, or fledglings, for example. Accordingly, the indirect (habitat) effects of ORVs and campers on birds are described in "Community Structure."

Community Structure

Bury, Luckenbach, and Busack (1977) studied the effects of repeated ORV (mainly motorcycles) use on creosote shrub habitat and associated birds in the western California desert. Control sites had more shrubs than did nearby ORV-use sites because of direct mechanical damage to shrubs by ORVs. Soil and ground vegetation between shrubs were disrupted on ORV sites. Heavily used sites had significantly fewer shrubs, ground cover was virtually absent, and there was clear evidence of shrub destruction. Bury, Luckenbach, and Busack (1977) believed that ORV disruption of vegetation and soil can disturb seed germination and thereby reduce the number of spring annuals. A reduction in annuals would in turn lead to a loss of seeds, forage, and the arthropods that feed on annuals. Top soil is lost and soil is compacted in ORV areas. By dispersing and burying seeds, ORV traffic near shrubs reduces food for birds (Bury, Luckenbach, and Busack 1977).

Bird censuses on three 4-ha areas (control, moderate ORV use, heavy ORV use) indicated important avifaunal differences. During 1974, Bury, Luckenbach, and Busack (1977) detected 5 times the number of breeding pairs and 10 times the avian biomass on the control site as they did on the moderately disturbed site. No breeding birds were detected on the heavily used site. Species (and number of individuals) with territories or nests on the control site were sage sparrow (two), Brewer's sparrow (one), black-throated sparrow (one), and LeConte's thrasher (one). Mourning doves and horned larks had nested on the control site earlier in the spring (as evidenced by recent nests) but did not have territories or nests during the census. The site that received moderate ORV use supported one territory each for the house finch (*Carpodacus mexicanus*) and black-throated sparrow, and both territories were in areas of reduced disturbance at that site. On the control site, 62 birds were foraging or detected on the ground: 38 horned larks; 8 Brewer's sparrows; 3 vesper sparrows (*Poocetes gramineus*); 2 each of mourning dove, black-throated sparrow, sage sparrow, and Wilson's warbler (*Wilsonia pusilla*); and 1 each of LeConte's thrasher, MacGillivray's warbler (*Oporornis tolmiei*), ash-throated flycatcher, Costa's hummingbird (*Calypte costae*), and American coot (*Fulica americana*). On the moderately used site, 19 individuals were foraging or observed on the ground: 17 horned larks, 1 house finch, and 1 black-throated sparrow. Bury,

Luckenbach, and Busack (1977) detected only one horned lark foraging in the heavily used area.

In 1975, 40-ha control and moderate-use sites were censused for breeding birds. Control sites had 2 times the number of species, 1.5 to 1.8 times the biomass, and 1.5 to 2.7 times the number of individuals that the moderately used areas had. Bury, Luckenbach, and Busack (1977) indicated that ORV-induced habitat changes were responsible for the observed differences in breeding avifaunas. They also suggested that ORV impacts to habitat and small-mammal populations would reduce the use of disturbed areas by migrant birds and raptors.

Webb (1983) studied ORV compaction of soils in the Mojave Desert in California and obtained results useful for assessing the potential for military wheeled-vehicle impacts to soils. Soil compaction from vehicles begins just below the surface and may extend to a depth of 1 m or more in some situations. Webb (1983) found that most of the compaction, decreases in infiltration rates, and increases in runoff rates occurred as a consequence of the first few ORV passes. Loamy sands and coarse gravelly soils with a wide range of particle sizes were most susceptible to compaction at all moisture contents, although the rate of compaction may be higher when soils are wet than when they are dry. Webb (1983) indicated that most soils will be compacted by ORV traffic but that sand and clays, in which most of the particle sizes are about the same, would be least affected. He noted, however, that when clay soils are wet, ORVs can compact them significantly. Fast-moving ORVs compact soil less and disrupt the soil surface more than do slow-moving ORVs. The importance of these results is that wheeled traffic in military training areas probably has similar impacts. Vegetation quantity and vigor—including growth (Webb 1983)—and therefore birds, are likely to be affected by these types of soil changes.

Hinckley, Iverson, and Hallet (1983) reported that ORV-induced water erosion rates may be 5 to 50 times greater than natural erosion rates. The runoff from one ORV-used drainage basin was eight times that of an adjacent unused basin, and basinwide erosion rates in the used area averaged 1 mm per year. The unused area produced no measurable sediment. In two ORV-use areas receiving 140 mm and 250 mm of precipitation per year, erosion rates were 150 mm and 220 mm per year, respectively. Plots subjected to simulated rainfall in ORV areas exhibited a 10- to 20-fold increase in erosion compared to nearby plots in unused areas. By compacting soils and reducing infiltration, ORV activity causes both the frequency and intensity of runoff to increase. ORVs destroy or disperse materials (e.g., rocks, vegetation) that stabilize the ground surface. ORVs also create smooth gulleys along which runoff accumulates and acquires a higher erosive capacity than would

otherwise be the case (Hinckley, Iverson, and Hallet 1983). To the extent that comparable soil changes originating from military maneuvers influence vegetation, birds that rely on that vegetation for various life-history needs also will be affected.

Gillette and Adams (1983) reviewed how ORV activity tends to accelerate wind erosion. ORV staging and parking areas ("pit areas") usually are large (10s to 100s of hectares) and have little vegetation left; therefore, these areas are quite susceptible to soil erosion by wind. Soils having a sandy texture, having low moisture content, occurring on a flat aspect, and supporting little vegetation are vulnerable to wind erosion. Alluvial fans, bajadas, and flats are among the most susceptible topographic features to ORV-induced wind erosion. Gillette and Adams (1983) believed that the principal factors influencing ORV-induced soil loss by wind were vegetation coverage and height, as well as length of ORV disturbance parallel to the direction of strong winds. Comparable maneuver-induced wind erosion, and its possible effects on plants—and thus birds—has potential to be a problem primarily just on installations in the southwestern United States, where the soil and topographic conditions mentioned here commonly occur (Gillette and Adams 1983).

Lathrop (1983b) studied the impact of ORVs (motorcycles and four-wheel-drive vehicles) on perennial vegetation in the California desert by comparing plant density and cover in disturbed (ORV) areas to those in undisturbed (control) areas. Most vegetation destruction was caused by direct contact with a vehicle's wheels and its undercarriage. ORV-induced soil compaction damaged root systems and germinating seeds. Compared to undisturbed areas, ORVs reduced plant density by 34 to 60 percent at dunes, in pit areas, on hillsides, and on race courses. Reductions in cover and species richness also occurred as a consequence of ORV traffic. Lathrop (1983b) concluded that concentrated ORV use in localized areas tended to reduce perennial cover the most; the average cover decline was 59 percent in such areas. Concentrated use of wheeled vehicles during military maneuvers would probably produce similar results in these desert habitats. Such drastic reductions in plant cover are bound to influence birds in some substantive way.

Because recreational campgrounds and troop encampments are likely to have a comparable impact on soils and ground and understory vegetation, a deeper understanding of how encampments for military maneuvers may influence bird communities can be gained by examining visitor and camper impacts on habitats and associated birds. Human trampling is a major factor that alters habitats in these situations. McDonnell (1981) studied the effects of long-term (13 to 30 year) trampling on dune vegetation in Massachusetts by comparing trampled sites to nearby undisturbed (control) sites. His disturbed sites experienced trampling from thousands of people each month during the summer and early fall. McDonnell

(1981) found that trampling during a 30-year period (considered severe) reduced vegetation cover by 79 percent and species richness by 83 percent. Heavy pressure (involving 24 to 28 years of trampling) resulted in 32 percent and 36 percent reductions in cover and richness, respectively. And moderate trampling (involving 13 years) caused significant (22 percent) declines in species richness, but nonsignificant (7 percent) declines in total cover. Sensitive plant species were eliminated by all levels of long-term trampling.

In a review of the effects of trampling on vegetation at wilderness campsites, Cole (1987) indicated that the most conspicuous impacts are injury to ground-level plants, causing in most species lower vigor and reproductive ability. Grasses and sedges, although damaged by trampling, tend to persist at campsites, whereas low shrubs, seedlings, and lichens usually incur severe damage and may be eliminated. All individuals of sensitive species may be killed at high levels of trampling. Some species may increase in abundance as a result of trampling, but this usually is because of competitive release or a change in microhabitat. Nonnative species tolerant of trampling frequently will be present at campsites but not in nearby undisturbed areas. All of these changes are usually accompanied by a reduction of cover and stature. When height and leaf area are reduced, photosynthetic area declines; thus, carbohydrate stores are lower, and this condition may influence plant vigor. Trampling from campers also compacts soil, reduces infiltration, and typically increases runoff and erosion. When vegetation is reduced on a site, the loss of organic horizons is accelerated by continued trampling. These various impacts on soils probably reduce germination and establishment of plants (Cole 1987).

Foin et al. (1977) and Garton, Hall, and Foin (1977) compared the vegetation and avifauna at a campground to those at a nearby control site that was used only occasionally by visitors. Trampling (along with fuel-wood gathering) contributed to significant ($P < 0.05$) differences between the following vegetation means (control site, campground site): natural litter depth (1.27 to 5.1 cm, < 1.27 cm); grass cover (26.3 percent, 16.2 percent); forb cover (35.0 percent, 10.6 percent); shrub cover (11.5 percent, 1.8 percent); log cover (5.2 percent, 0.0 percent); number of trees 0 to 1.5 m in height (84.5/0.07 ha, 49.1/0.07 ha); number of trees 1.5 to 3 m in height (48.8/0.07 ha, 27.2/0.07 ha); number of trees 3 to 4.6 m in height (20.9/0.07 ha, 12.7/0.07 ha); and number of trees 4.6 to 6.1 m in height (10.8/0.07 ha, 7.6/0.07 ha). Apparently, trampling contributed to substantial suppression of the understory at the campground site. Dark-eyed juncos (*Junco hyemalis*) were 4.7 times as abundant outside the campground as they were inside the campground; from June to August 1974, their abundance increased 52.3 percent in the control area but declined 57.3 percent in the campground. Brown-headed cowbirds and Brewer's

blackbird (*Euphagus cyanocephalus*) were abundant at the campground (80.5/ha, 302.5/ha, respectively), but neither species was recorded for the control site. Although American robins (*Turdus migratorius*) were more abundant at the campground (116/ha) than at the control site (22.5/ha), their abundance declined between June and August much more rapidly at the campground (73.9 percent decline) than on the control site (12.5 percent decline). Varied thrushes (*Ixoreus naevius*) were more common on the control site (24/ha) than on the campground site (16/ha). All of these birds are omnivorous ground-feeding species, but each was affected somewhat differently by the camper-induced habitat changes. Some species seemed to be attracted and some seemed to be repelled.

Blakesley and Reese (1988) compared the use of campground and noncampground sites by birds in riparian zones. They detected significant ($P < 0.05$) differences between the following vegetation means (noncampground sites, campground sites): natural litter depth (0.48 cm, 0.23 cm); grass cover (16.1 percent, 31.2 percent); cover of dead woody vegetation (9.6 percent, 1.7 percent); total trees per 0.045 ha (28.3, 19.9); and shrubs or saplings per 0.045 ha (109.6, 52.5). Species with lower abundances in campgrounds were the broad-tailed hummingbird, dusky flycatcher (*Empidonax oberholseri*), willow flycatcher (*E. traillii*), black-capped chickadee (*Parus atricapillus*), lazuli bunting (*Passerina amoena*), song sparrow (*Melospiza melodia*), and fox sparrow (*Passerella iliaca*). Except for the black-capped chickadee, all of these species nest on the ground, in shrubs, or in small trees—the components of vegetation that were degraded or reduced by campers at campground sites. Species with higher abundances in campgrounds were Swainson's thrush, American robin, gray catbird (*Dumetella carolinensis*), warbling vireo, yellow warbler (*Dendroica petechia*), MacGillivray's warbler, and black-headed grosbeak. With the exception of Swainson's thrush and MacGillivray's warbler, all of these species nest in trees—a component that evidently was still in adequate quantity (19.9/0.045 ha) on campgrounds.

Aitchison (1977) studied bird densities and species composition at a campground and on an adjacent control plot that was not used by campers. In 1973, a 40 percent decrease in avian density occurred on the campground after it was opened for the year. In making room for tents and removing branches for firewood, campers destroyed about 30 percent of the Steller's jay (*Cyanocitta stelleri*) nests and 20 percent of the American robin nests. Parulid warblers, solitary vireos, broad-tailed hummingbirds, and hairy woodpeckers (*Picoides villosus*) abandoned their nests but did occasionally feed in the campground after it was opened. On the control plot, avian density increased 12.1 percent because of the arrival of midsummer breeders (red-faced warbler [*Cardellina rubrifrons*], western wood-pewee, and hepatic tanager (*Piranga flava*)). Following the opening of the campground, species

richness declined on the campground from 12 to 8, but on the control plot it increased from 9 to 12.

After the campground was opened in 1974, avian densities on the campground decreased 25 percent, but they increased 87.3 percent on the control plot. Species richness declined from 16 to 13 on the campground and rose from 8 to 13 on the control plot after the opening of the campground. After the campground was opened in 1975, avian densities on the control plot rose 149.8 percent, but on the campground they increased by only 44.4 percent. Species richness climbed from 7 to 17 on the control plot, but on the campground it increased only from 10 to 12. In summarizing his results, Aitchison (1977) indicated that, although bird densities were similar between the campground and control plot before the opening date each year, densities and richness decreased (or did not increase as much) on the campground relative to the control site. Also there was a shift in the community to heavier-bodied birds in the campground due in part to habitat alteration on the campground (Aitchison 1977).

Guth (1978) compared bird densities and species composition in mature forest to those for campgrounds. He found that bird density was low (2.50 to 3.27 birds/0.8 ha) for forest and forest-edge sites, somewhat higher for forest with deciduous and coniferous vegetation (3.88 birds/0.8 ha), and considerably higher in campgrounds (7.67 to 10.00 birds/0.8 ha). The campgrounds that Guth studied (1978) were a mosaic of open- and closed-canopy habitats, deciduous and coniferous vegetation, and numerous clumps of shrubs and saplings that were kept at an early successional stage by frequent habitat disturbance from campers. The bird species that used this type of habitat occurred in greater densities relative to those that used mature forest. Campgrounds had only slightly higher richness compared to mature forest sites (33, 32, respectively), and species diversity was just a bit higher at campgrounds than in mature forest (9.7, 9.5, respectively). However, there were substantial differences in composition. Guth (1978) detected 14 species in mature forest habitats that were not in campgrounds: black-capped chickadee, ovenbird (*Seiurus aurocapillus*), mourning warbler (*Oporornis philadelphia*), veery, blackburnian warbler (*Dendroica fusca*), indigo bunting (*Passerina cyanea*), ruffed grouse (*Bonasa umbellus*), black-throated green warbler (*Dendroica virens*), wood thrush (*Hylocichla mustelina*), black-and-white warbler, winter wren (*Troglodytes troglodytes*), pileated woodpecker (*Dryocopus pileatus*), red-breasted nuthatch, and brown creeper (*Certhia americana*). Guth (1978) recorded 14 species at campgrounds that were not in mature forest: common grackle (*Quiscalus quiscula*), yellow warbler, tree swallow (*Tachycineta bicolor*), northern flicker (*Colaptes auratus*), brown thrasher (*Toxostoma rufum*), barn swallow (*Hirundo rustica*), northern rough-winged swallow (*Stelgidopteryx serripennis*), warbling vireo, song

sparrow, black-throated blue warbler (*Dendroica caerulescens*), European starling, American goldfinch (*Carduelis tristis*), house wren (*Troglodytes aedon*), and yellow-throated vireo (*Vireo flavifrons*). Guth (1978) noted that the species detected in campgrounds were mostly widespread species and that many rare forest species were not observed at campgrounds. Based on these various examples, camper-caused changes in habitat structure seem to have the potential to influence bird species composition, richness, and abundance appreciably. Vegetative impacts from similar use of sites for military bivouacs would probably have similar consequences on bird communities.

The information summarized in this section on indirect (habitat) effects of recreational disturbance on birds indicates that ORVs can affect soils, vegetation, and birds. Some vehicles used in military maneuvers are four wheel drive. The impacts of wheeled traffic are soil- and vegetation-specific; nevertheless, for the soils, climates, and habitats described, ORV-induced changes probably approximate those that military wheeled vehicles would cause. Behavioral and reproductive impacts on birds due to ORVs have not been examined adequately, but extensive habitat changes would likely alter behavior and reproductive performance. By compacting soils, exacerbating erosion, and altering habitat structure and composition through trampling, campers can influence the densities of birds and avian community composition. To the extent that troop encampments change soil and vegetation in these ways, they too probably alter local avian densities, richness, and composition.

4 Quality of Existing Data

During the literature search for this report, the following factors were recorded:

- type of military, recreational, or natural-resource disturbance in question
- study design
- dependent variable(s)
- maximum number of independent units
- months of study
- levels of disturbance studied
- whether extraneous variation was controlled.

Table 1 lists information for studies of direct and indirect (habitat) effects of military maneuvers on birds. Table 2 lists information for studies of direct and indirect (habitat) effects of maneuver-like recreational and natural-resource activities. Some studies are listed more than once because they involved analysis of more than one dependent variable. This chapter summarizes the information in Tables 1 and 2 and comments on the quality of existing data for establishing causal relations between military maneuvers and changes in avian behavior, reproduction, and community structure.

Effects of Military Activities on Birds

Less than a dozen published studies were found that specifically addressed the effects of military disturbances on birds or their habitats. One was anecdotal and reported few details. Although some installations may have unpublished reports, those reports would not be peer-reviewed. The studies reviewed covered the range of major military activities that might be expected to occur during maneuvers or training activities. Only one project was implemented as an experiment. Constraints on funding, personnel, time, appropriate study areas, and other resources may have prevented true experiments from being completed. Without well-designed experiments, causal relations cannot be established. Although a number of studies recognized "control" and "treated" groups, investigators did not randomly assign treatments to experimental units, did not manipulate the independent variable(s), did not have spatial and temporal controls, or all of these.

Table 1. Design and analysis of studies of direct and indirect (habitat) effects of military maneuvers on avian behavior, reproduction, and community structure.

Type of Maneuver	Design ^a	Dependent Variable(s) ^b	Maximum Number of Independent Units ^c	Months of Study ^d	Levels of Disturbance Studied ^e	Extraneous Variation Controlled ^f	Reference
Strafing	NR	Roosting Behavior	NR	NR	NR	NR	Tennesen (1993)
Helicopter Overflights	O	Nesting Behavior and Success	29	2 for first year, 1 for second year	2	No	Andersen et al. (1989)
Tank Movements & Artillery Fire	O	Post-breeding Behavior	1	3 for 1 year	2	No	Andersen et al. (1986)
Tank & Helicopter Movements, Artillery Fire	O	Home-range Shifts; Extra-home Range Movements	16	2 for each of 3 years	2	Yes	Andersen et al. (1990)
Tank Movements & Artillery Fire	NR	Hunting Behavior	NR	NR	2	NR	Tennesen (1993)
Tracked-vehicle Movements	O	Avian Biomass, Diversity and Composition; Habitat Structure	4	< 1 for 1 year	2	Yes	Diersing and Severinghaus (1984)
Tracked-vehicle Movements	O	Plant Species Richness, Biomass, and Composition	22	2 for each of 3 years	4	No	Forbes (1992)
Tracked-vehicle Movements	O	Avian Biomass, Diversity and Composition; Habitat Structure	9	1 for each of 3 years	5	No	Severinghaus and Severinghaus (1982)
Tracked-vehicle Movements	E	Plant Species Composition; Frequency of Bare Ground	48	2 for 1 year	5	Yes	Wilson (1988)
Tracked-vehicle Movements & Bivouacs	O	Avian Biomass and Density; Habitat Structure	23	1 for 1 year	4	Yes	Krzysik (1984)
Tracked-vehicle Movements & Bivouacs	O	Vegetation Density, Richness and Stability	1008	NR	4	Yes	Lathrop (1983a)

^a E = Experimental, with randomly assigned treatments and controls; independent variables manipulated by investigator. O = Observational; control and treated groups recognized, but neither random assignment of experimental units nor experimental manipulation of independent variables by investigator occurred. NR = Not reported by author.

^b Response variable measured.

^c NR = not reported by author. An independent experimental or observational unit was frequently an individual bird or nest, but sometimes it actually was an entire colony or area.

^d Duration entered to the nearest month; NR = not reported by author. Period reported is total time spent collecting actual response data for each year of the study.

^e Number includes control level; NR = not reported by author. Number pertains to disturbance levels applied to the dependent variable(s) listed.

^f Explicit control of extraneous variation occurred through the study design (e.g., via randomization) or data analysis; the influences of habitat, weather, seasonal timing, or other variables were removed before interpretation of effects of military activities. NR = not reported by author.

Table 2. Design and analysis of studies of direct and indirect (habitat) effects of recreational or natural-resource activities on avian behavior, reproduction, and community structure.

Recreational or Natural-Resource Activity	Design ^a	Dependent Variable(s) ^b	Maximum Number of Independent Units ^c	Months of Study ^d	Levels of Disturbance Studied ^e	Extraneous Variation Controlled ^f	Reference
Helicopter Overflights	O	Nesting Behavior	117	< 1 for 1 year	1	No	Carrier and Melquist (1976)
Helicopter Overflights	S	Nesting Behavior	220	3 for 1 year	2	Yes	Kushlan (1979)
Helicopter Overflights	E	Feeding Behavior	876	< 1 for each of 4 years	13	Yes	Ward and Stehn (1989)
Helicopter Overflights	O	Nesting Behavior	270	1 for each of 3 years	10	Yes	Watson (1993)
Oil-well Construction	O	Breeding Behavior	1	< 1 for each of 4 years	2	No	Mueller and Glass (1988)
Driving on Beaches	O	Habitat Use	NR	5 for each of 5 years	3	Yes	Flemming et al. (1988)
Driving on Beaches	O	Reproduction	NR	NR	NR	NR	Melvin et al. (1991)
Driving on Beaches	O	Habitat Use During Migration	1	3 for each of 18 years	Continuous Variable	Yes	Pfister et al. (1992)
Driving on Beaches	O	Habitat Use	16	2 for first year, 7 for second year	NR	No	Purdy et al. (1987)
Hiking	O	Habitat Use	36	< 1 for each of 3 years	2	No	Buehler et al. (1991)
Hiking	O	Roosting Behavior	2	12 for 1 year	4	No	Burger (1981)
Hiking	O	Habitat Use	24	6 for 1 year	1	Yes	Burger (1986)
Hiking	O	Habitat Use	NR	5 for each of 5 years	3	Yes	Flemming et al. (1988)
Hiking	O	Nesting and Foraging Behavior	13	3 for each of 3 years	Continuous Variable	Yes	Grubb and King (1991)
Hiking	O	Nesting Behavior	NR	< 1 for 1 year	1	No	Hand (1980)
Hiking	O	Nesting Behavior	28	3 for each of 3 years	8	No	Hooper (1977)
Hiking	O	Number of Young Fledged	1	3 for each of 3 years	8	No	Hooper (1977)
Hiking	O	Predator Encounters by Ducklings	40	3 for 1 year	1	No	Keller (1991)
Hiking	O	Predation	478	2 for 1 year	1	No	Kury and Gochfield (1975)
Hiking	O	Number of Chicks	6	< 1 for each of 3 years	2	No	Picozzi (1971)
Hiking	O	Breeding Bird Density	9	3 for 1 year	Continuous Variable	Yes	van der Zande et al. (1984)

Recreational or Natural-Resource Activity	Design ^a	Dependent Variable(s) ^b	Maximum Number of Independent Units ^c	Months of Study ^d	Levels of Disturbance Studied ^e	Extraneous Variation Controlled ^f	Reference
Hiking	O	Breeding Bird Density	34	5 for each of 3 years	2	Yes	van der Zande and Vos (1984)
Hiking	O	Number of Chicks per Adult	22	1 for each of 22 years	3	No	Watson (1988)
Hiking	O	Breeding Behavior	12	3 for each of 3 years	2	No	Yalden and Yalden (1990)
Hiking, Tour Groups	O	Nesting Behavior	5,991	3 for each of 6 years	3	Yes	Anderson and Keith (1980)
Hiking, Tour Groups	O	Predation	5,991	3 for each of 6 years	3	Yes	Anderson and Keith (1980)
Hiking, Tour Groups	O	Productivity	5,991	3 for each of 6 years	3	Yes	Anderson and Keith (1980)
Exploring on Foot	O	Habitat Use	16	2 for first year, 7 for second year	NR	No	Purdy et al. (1987)
Driving on Roads	O	Feeding Behavior	34	2 for each of 2 springs, 2 for each of 2 falls	1	Yes	Bélanger and Bédard (1989)
Driving on Roads	O	Nesting Success	36	6 for each of 2 years	16	Yes	Fraser et al. (1985)
Driving on Roads	O	Nesting Behavior	10	2 for each of 2 years	1	No	Henson and Grant (1991)
Driving on Roads	E	General Behavior	> 600	12 for first year, 1 for second year	5	Yes	Klein (1993)
Driving on Roads	O	Reproduction	16	2 for first year, 7 for second year	NR	No	Purdy et al. (1987)
Driving on Roads	O	Reproductive Parameters	306	3 for each of 5 years	1	Yes	Varland and Loughin (1993)
Vehicles On/Off Roads	O	Number of Young Fledged	1	5 for each of 2 years	1	No	Lee (1981)
Vehicles On/Off Roads	E	Reproduction	8	1 for each of 2 years	1	Yes	White and Thurow (1985)
Parked Vehicle	E	Breeding Behavior	8	< 1 for each of 2 years	3	Yes	Baydack and Hein (1987)
Picnicking	O	Success of Raising Young	823	1 for each of 3 years	2	No	Hunt (1972)
Picnicking	O	Nesting Behavior	NR	1 for each of 3 years	2	No	Hunt (1972)
Off-Road Vehicles	O	Richness, Abundance & Biomass for Breeding and	7	< 1 for each of 2 years	3	Yes	Bury et al. (1977)

Recreational or Natural-Resource Activity	Design ^a	Dependent Variable(s) ^b	Maximum Number of Independent Units ^c	Months of Study ^d	Levels of Disturbance Studied ^e	Extraneous Variation Controlled ^f	Reference
		Foraging Birds					
Off-Road Vehicles	O	Plant Density, Cover and Richness	9	5 for first year, 7 for second year	2	Yes	Lathrop (1983b)
Off-Road Vehicles	E	Soil Properties	74	1 for 1 year	5	Yes	Webb (1983)
Camping	O	Avian Density and Richness; Vegetation Structure	2	3 for first year, 5 for second year, 2 for third year	2	No	Aitchison (1977)
Camping	O	Avian Density; Vegetation Structure	111	2 for 1 year	2	Yes	Blakesley and Reese (1988)
Camping	O	Avian Density and Diversity; Vegetation Structure	2	1 for 1 year	2	No	Foin et al. (1977)
Camping	O	Avian Density and Composition	104	< 1 for 1 year	8	No	Guth (1978)
Camping	O	Plant Cover and Diversity	8	1 for 1 year	4	No	McDonnell (1981)

^a E = Experimental, with randomly assigned treatments and controls; independent variables manipulated by investigator.
S = Semi-experimental; control and treated groups recognized, but either no random assignment of treatments to units or no experimental manipulation of independent variable(s) occurred.

^b O = Observational; control and treated groups recognized, but neither random assignment of experimental units nor experimental manipulation of independent variables by investigator occurred.

^c Response variable measured.

^d NR = not reported by author. An independent experimental or observational unit was frequently an individual bird or nest, but sometimes it actually was an entire colony or area.

^e Duration entered to the nearest month; NR = not reported by author. Period reported is total time spent collecting actual response data for each year of the study; some figures are estimated.

^f Number includes control level; NR = not reported by author. Some disturbances were continuous variables (e.g., number of vehicles per unit time) and could not be categorized into discrete levels. Number pertains to disturbance levels applied to the dependent variable(s) listed.

Explicit control of extraneous variation occurred through study design (e.g., via randomization) or data analysis; the influences of habitat, weather, seasonal timing, or other variables were removed before interpretation of effects of recreational or natural-resource activities. NR = not reported by author.

Virtually all of these projects were observational studies, which in general are capable of demonstrating only associations, at best. No study reviewed attempted to separate out the confounding influences of habitat change, noise, and the mere presence of people and vehicles that are all simultaneously part of military maneuvers.

Many avian behaviors were studied, but little was reported about actual effects on reproduction. Several studies went into depth on how military activities (actual or simulated) indirectly influenced avian density, richness, composition, and biomass via habitat alteration. No nonbreeding-season studies were found. Only three studies considered the specific effects of tracked vehicles on just vegetation, although such knowledge could be extremely helpful in predicting impacts on birds.

Many of the studies suffered from small sample sizes. The numbers of independent units in Table 1 are optimistic estimates based on what was reported. But repeated observations on the same individual—a common occurrence in these references—cannot typically be considered independent. Observations of different nearby individuals responding to a single disturbance (e.g., helicopter flying over a nesting colony) are not independent either because the reaction (flight or freeze) by one individual probably affects that of other individuals in the vicinity. Furthermore, responses by several individuals to a single, large-scale disturbance may be correlated because of extraneous factors associated with the event itself (e.g., weather, time of year). Lack of independence usually leads invalidly to larger test statistics and (hence) artificially small *P* levels. Hurlbert (1984), in his review of the ecological literature, found pseudoreplication to be widespread, even in studies published in leading journals.

Some studies reviewed spanned 2 to 3 years so birds could be captured, telemetered, and followed to obtain baseline data. But in most cases, only 1 or 2 months during 1 to 3 years were spent collecting actual data on responses to disturbances. Reports of long-term or year-around data on avian responses to military disturbance were not found. Resource constraints were probably the main problem; and if more resources had been available, investigators probably would have carried out additional work. About half of the analyses examined involved only a disturbed and an undisturbed group; the other half dealt with three to four levels or types of disturbance, which is essential for identifying the specific level or type of disturbance causing an impact (Gutzwiller 1993). Only half of the investigators controlled for extraneous variation.

In general, data on the direct and indirect (habitat) effects of military maneuvers on birds are not rigorous, although they are perhaps the best that could have been

obtained under the circumstances. Descriptions of results in this review give authors' opinions and interpretations the benefit of the doubt. Despite the weaknesses in this data set, the studies suggest that military maneuvers can have a significant effect on birds. Even though exact cause-and-effect relations in most cases (see Table 1) cannot be discerned, important associations seem evident. The results are logical and consistent with the biology of the species involved. For these latter reasons, the data should be taken seriously by those on installations who must balance environmental compliance requirements for avian species with military training missions.

Effects on Birds From Recreational Disturbance and Natural-Resource Development and Management

By describing effects of maneuver-like disturbances on birds, the literature on recreational disturbance and natural-resource development and management activities provided additional information about the potential for military maneuvers to affect birds. The impact on birds and habitats from helicopters, heavy machinery, roads, wheeled vehicles on roads, off-road vehicles, hiking, picnicking and camping were assessed. Only five of the studies were experimental (Table 2); thus, observational work dominated this sector of the literature too. General habitat use and habitat use during migration, as well as breeding, nesting, feeding, and roosting behavior, were examined. Unlike the military literature, a number of studies actually focused on reproduction. Several studies examined how recreation-induced habitat alteration influenced avian densities, richness, composition, and biomass.

Of the separate papers that reported sample sizes, the proportion that relied on small (< 30) samples was smaller for this literature (19 of 37, 51 percent) than it was for the military-related literature reviewed (7 of 9, 78 percent). Pseudoreplication was just as pervasive in the recreation and natural-resource papers as it was in the military papers. Response data were collected, on average, during more months per year by authors of the recreational and natural-resource literature (mean = 2.7 months per year, $n = 39$) than by those of the military literature (mean = 1.6 months per year, $n = 8$). Response data also were collected during a greater number of years (field seasons) for recreational (mean = 3.2 years, $n = 39$) than for military studies (mean = 1.9 years, $n = 8$). Only a few recreation-related studies assessed long-term responses; one study each involved 5, 6, 18, and 22 years of response data. Only about half of the investigators controlled for extraneous variation.

Overall, the recreational and natural-resource publications reviewed were not rigorous. Most exhibited the problems of minimally replicated, nonrandomized observational studies, presumably because of resource constraints faced by investigators. Although causal relations cannot be established by most of these studies, they do provide examples of the types of impacts that may occur. Many of the studies detected the same basic results, even though different study areas, bird species, and designs were used; this suggests that there really are impacts on birds from the activities examined. The sheer number of impacts reported by investigators also argues that behavior, reproduction, and community structure were probably affected in important ways. It is reasonable to believe that maneuver activities that generate comparable disturbances would have similar consequences.

5 Knowledge Gaps

One objective of this literature review is to identify major knowledge gaps on the subject of actual and potential effects of military activities on birds. The primary types of information needed to fill the voids in current understanding of how military maneuvers influence avian behavior, reproduction, and community structure are:

- Data from long-term experimental studies that examine direct impacts of rotor-winged, tracked, and wheeled vehicles on a variety of avian taxa.
- Data from long-term experimental studies that examine direct impacts of rotor-winged, tracked, and wheeled vehicles on birds' habitats so a better understanding of indirect effects can be developed.
- Data from studies that use the same methods of design and analysis, but that are applied in various contexts, including different locations, habitats, and climate regimes. The purpose would be to determine whether there are commonalities among the different contexts that might be useful for prediction.
- Data from work that manipulates the frequency, duration, seasonal timing, periodicity, and spatial scale of military disturbances. Also needed are data from experiments that involve different numbers of troops, vehicles, or both.
- Data from telemetered birds that will reveal their immediate and long-term behavioral reactions to military disturbance.
- Data about impacts of maneuvers on breeding-, foraging-, and stopover-site fidelity and tenacity.
- Data on the degree to which birds may habituate to or learn to tolerate military disturbances.
- Data about how the history of military disturbance at a site influences birds.
- Data on cumulative, interactive, and lag effects of military activities on birds.
- Data from experiments that separate out the potentially confounded effects of noise, habitat alteration, and the presence of troops and vehicles.

6 Summary

The major conclusions from this literature review on the actual and potential effects of military maneuvers on avian behavior, reproduction, and community structure are summarized as follows:

- Reported impacts on birds associated with maneuvers, or maneuver-like disturbances, included abandonment of nests; shifts in habitat use; changes in feeding, breeding, and roosting behavior; and alterations of reproduction, predation, density, richness, composition, and biomass.
- Reported studies indicate that the structure and floristic composition of avian habitats can be altered in significant ways during maneuvers by tracked and wheeled vehicles and by encampments. Depending on the environment, these impacts may last for decades.
- There is considerable variation within and among species in their responses to military and maneuver-like disturbances. The evidence suggests that some species may learn to tolerate or habituate to certain military disturbances. In these cases, few or no detrimental effects usually accrue.
- Most of the data reviewed were obtained from observational studies. Nevertheless, the many reported impacts that are consistent with what is known about the species' life-history needs and autecology support the contention that maneuvers can generate serious negative effects on birds.
- Examination of effects from maneuver-like recreational (e.g., ORV events, hiking) and natural-resource (e.g., helicopter overflights) activities revealed the variety of ways in which actual maneuvers may be influential.
- Few peer-reviewed studies of how military activities influence birds are available, and numerous gaps in the knowledge about this issue must be filled before installations will be able to meet their dual responsibility of preserving birds and training effective combat troops.
- Current data are probably the best that could have been obtained under the various resource constraints faced by investigators, but they are not adequate for discerning causal relations.
- Almost no studies used the same sampling or analysis techniques, which makes it difficult to draw valid inferences about the effects of disturbances on birds under different conditions.

- Small (< 30) sample sizes and lack of control for extraneous variation probably prevented some impacts from being detected (i.e., statistical power was weak), and some reported effects were probably artifacts of pseudoreplication.
- Many of the studies reviewed did not control for the effects of the investigators themselves.
- Avian responses to military and maneuver-like disturbances can be extremely context-specific, so experiments for each species-installation setting may be necessary to assess associated impacts.

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